



The Influence of Gelatin on the Transference Numbers of Hydrochloric Acid by the Concentration Cell Method

DISSERTATION

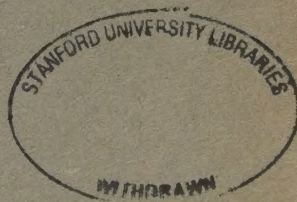
**PRESENTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR
THE DEGREE OF DOCTOR OF PHILOSOPHY IN THE GRADUATE
SCHOOL OF THE OHIO STATE UNIVERSITY**

BY

WALTER HARRISON MORAN, B. A., M. Sc.

The Ohio State University

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UNCLASSIFIED
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THE INFLUENCE OF GELATIN ON THE TRANSFERENCE
NUMBERS OF HYDROCHLORIC ACID BY THE
CONCENTRATION CELL METHOD

I. INTRODUCTION

In arecent work of Ferguson and France (1) it was predicted, "That a definite adsorption complex or additive chemical compound, which undergoes dissociation is formed between gelatin and electrolytes." It was further predicted that in case of alkali electrolytes, the adsorption complex or chemical compound would dissociate in such a way that the anion would lose its identity, likewise in case of acid electrolytes the cation would lose its identity and in case of neutral electrolytes, there would be no effect. It was with the view of substantiating this prediction, that the action of hydrochloric acid was investigated.

II. REVIEW OF PREVIOUS WORK.

In each of the three articles which occur in the literature, on the influence of colloids on transference numbers the analytical method was used.

Paul Richter (2) investigated the effect of gum arabic, peptone, agaragar, and gelatin on the transference of the aniona of lithium and potassium chlorides. With the exception of gelatin, he used the same substances on hydrochloric acid. Richter found in every instance that the transference on the anion decreased with increase of gelatin content of the solution. In many cases the decrease was proportional to the concentration of the gelatin.

A. Mutscheller (3 & 4) investigated the influence of gelatin on the transference numbers of silver nitrate, cupric sulfate and zinc sulfate solutions to which were added definite quantities of a one percent gelatin solution.

Mutscheller found as increasing amounts of gelatin solution were added that the transference on the anion decreased to zero and assumed negative values with a corresponding increase in transference on the cation. This he explains by the adsorption of the anion by the gelatin.

Rene Audbert (5) used gelatin in concentration cells of the type $\text{AgI} - \text{AgNO}_3$ and found a lowering of the electromotive force which he explains by selective adsorption of the Ag^+ ion by the gelatin added.

J.W. Corran (6) measured the influence of varying concentrations of sucrose -0% to 70% on concentration cells of potassium chloride with and without transference. He found the transference on the potassium ion was constant up to 50% sucrose concentration. At higher concentrations, it tends to increase slightly.

III. THEORETICAL INVESTIGATION

In this investigation the concentration cell method as developed by A.L. Ferguson was employed. (7) This involved the measurement of the potentials of a concentration cell without diffusion.

$$E = \frac{2RT}{F} \ln \frac{C_1}{C_2} \quad (1)$$

A concentration cell with diffusion and reversible with respect to the cation,

$$E_H = 2N_a \frac{RT}{F} \ln \frac{C_1}{C_2} \quad (2)$$

and a concentration cell with diffusion reversible with respect to the anion,

$$E_{C1} = 2N_c \frac{RT}{F} \ln \frac{C_1}{C_2} \quad (3)$$

Equation (3) the expression for the electromotive force for a concentration cell with transference divided by equation (1), the expression for the electromotive force without transference gives,

$$\frac{E_{C1}}{E} = N_c \quad (4)$$

which expresses the transference number of the cation in terms of E_{C1} and E . In a similar way the expression

$$\frac{E_H}{E} = N_a \quad (5)$$

is obtained from equations (1) and (2).

In this work the gelatin was introduced into the boundary between the acid concentration solutions and its effect on the boundary potential was calculated by the following equation derived by Ferguson.

$$E_B = \frac{E_{C1} E_H}{2} = (1-2N_a) \frac{RT}{F} \ln \frac{C_1}{C_2} \quad (6)$$

IV. APPARATUS AND MATERIALS

The potential measurements were made with an Otto Wolff 15000 ohm potentiometer using two Weston certified cells, one as a check on the other. Baker's Analyzed mercurous chloride was used. Since it was found impossible to purify tank hydrogen satisfactorily, the hydrogen used was generated by electrolyzing 5 N. sodium hydroxide in a generator of the Bodenstein and Pohl type (8). The hydrogen electrodes were of the ordinary foil type coated with platinum black. The mercury used was washed with a dilute solution of mercurous nitrate and distilled five times in a Hulett mercury still. Ash free gelatin as prepared Ada M. Field was used throughout this investigation. (9). The solutions used in this investigation were prepared from commercial C.P. hydrochloric acid and conductivity water.

All measurements were made with the Weston standard cells and the concentration cells contained in an electrically heated and regulated oil thermostat, which was maintained at a temperature of $25^{\circ} \pm 0.01^{\circ}$.

The arrangement of the cells and the location of the potentials are shown in Fig. I. The procedure fol-

lowed in making measurements is described by Ferguson, A.L., and France, W.G. (10).

As a preliminary step in the investigation it was necessary to determine the transference number of the anion of hydrochloric acid for 0.1 M. and 0.01 M. solutions. The transference on the anion was found to be 0.1699 ± 0.00179 which agrees favorably with the value 0.1702 corrected to 25°, which was obtained by Noyes, and Sammet. (11)

V. THE INFLUENCE OF GELATIN ON THE TRANSFERENCE NUMBERS OF HYDROCHLORIC ACID.

The gelatin was introduced into the concentration cells as shown in Fig. I and as described by Ferguson and France. (12) Measurements were made with concentrations of gelatin varying from 0.5 to 20%. In all twenty-eight runs were made, the results of which are summarized in Table III. Tables I and II are given, as examples of individual runs.

In Tables I and II column E_H contains the potentials of the hydrogen concentration cell with diffusion, $Pt_{H_2} | 0.1 \text{ M HCl} | 0.01 \text{ M HCl} | Pt_{H_2}$; column E_{Cl} those of the chloride concentration cell with diffusion, $Hg | Hg_2Cl_2.0.01 \text{ M HCl} | 0.1 \text{ M HCl} . Hg_2Cl_2 | Hg$; column $E_{0.1}$ the potentials of the cell $Pt_{H_2} | 0.01 \text{ M HCl}, Hg_2Cl_2 | Hg$. The columns headed "E by $E_H + E_{Cl}$ " contains the sum of the values recorded in columns E_H and E_{Cl} . The column "E by $E_{0.01} - E_{0.1}$ " contains the differences between the values recorded in columns $E_{0.01}$ and $E_{0.1}$.

In Table III the headings of columns 2, 3, 4, and 5 have the same significance as those given for Tables I and II.

TABLE I

5 % Gelatin

No.	Date	Time	Bar.	ϕ	E_H	E_{Cl}	$E_{O.1}$	$E_{O.01}$	$E_H - E_{Cl}$	E by	E by
										$E_{O.01} - E_{O.1}$	
1	5-9-23	3:15 PM	735.3				0.39656	0.51101			
2	"	5:00 "	736.9				656	101			
3	"	7:00 "	738.6				665	122			
4	"	7:30 "	739.2		0.7444	0.04015	667	121	0.11459	0.11454	
5	"	10:00 "	739.2		444		667	121			
6	"	12:00 "	739.9		422	3989	688	122	411	423	
7	5-10-23	1:30 AM	741.3		422		690	122			
					420	980	722	125	400	403	
					420		722	125			
					462	899	735	147	361	412	
					462		735	147			
Average					0.07437	0.03971	0.39703	0.51129	0.11408	0.11426	

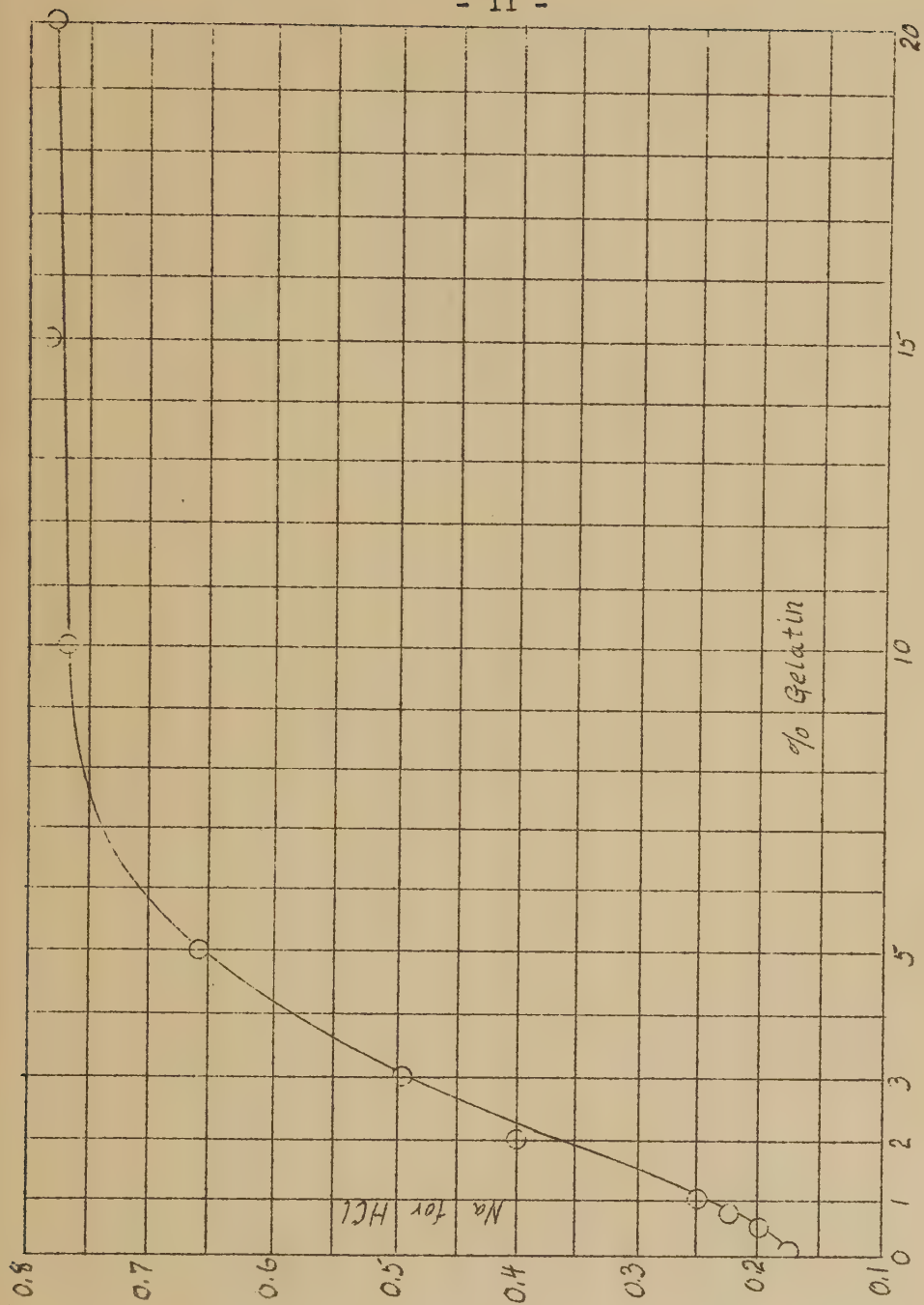
Set up 10:30 PM, May 8, 1923.

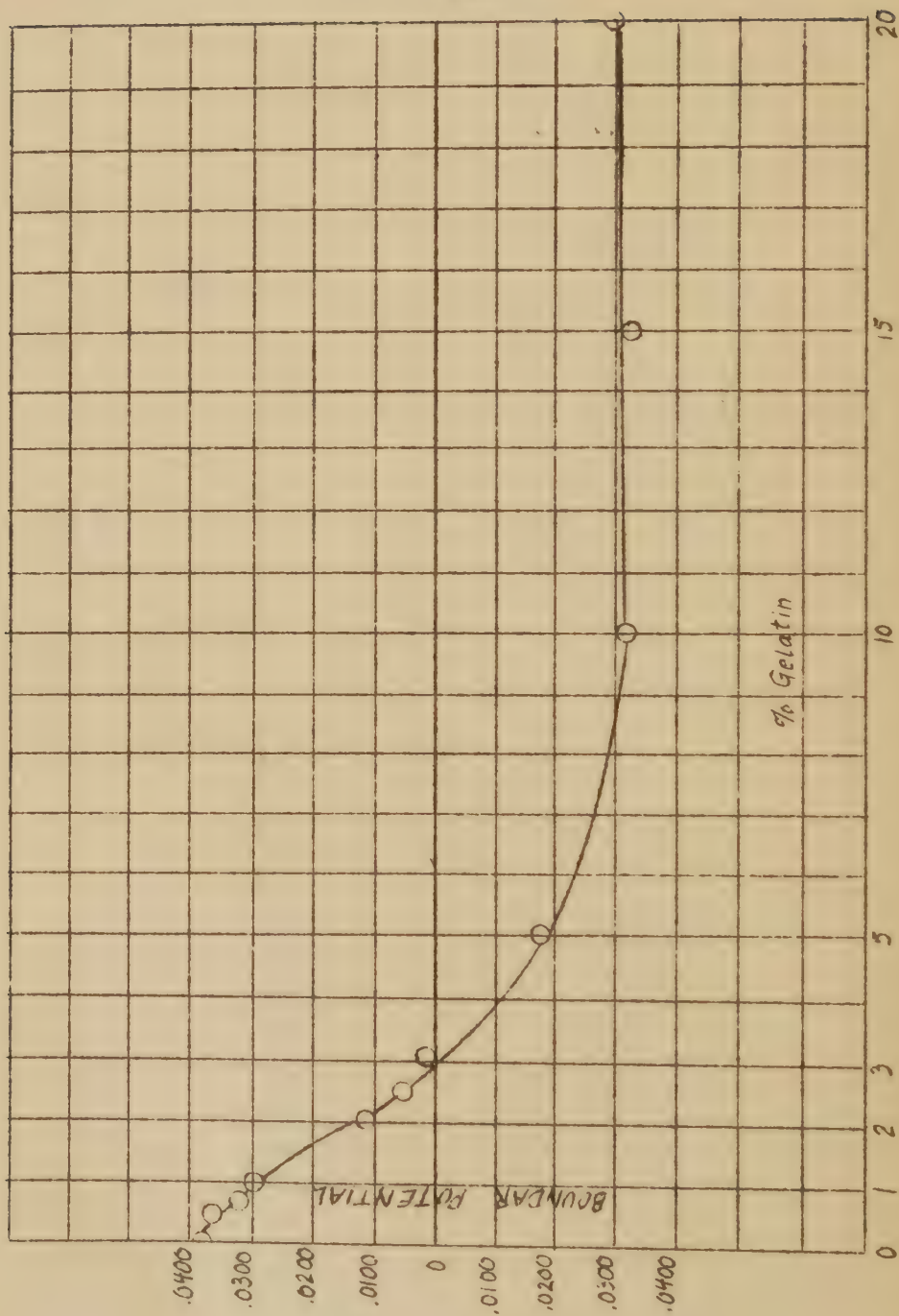
Boundaries put in 7:30 PM, May 9.

TABLE II
Determination l_a , 20 % Gelatin

No.	Date	Time	Bar.	T_H	E_{Cl}	$E_{0.1}$	$E_{0.01}$	$E_H + E_{Cl}$	$E_{by} - E_{0.01}$	$E_{by} - E_{0.1}$
1	6-4-23	3:00 PM	743.3			0.39757 757	0.51072 072			
2	"	4:00 "	742.7			767 767	075 075			
3	"	5:00 "	742.3	0.08697 697	0.02642	753 753	091 091	0.11339	0.11338	
4	"	7:30 "	742.3	889	487	765 765	103 103	376	338	
5	6-5-23	12:30 AM	743.2	932 932	415	765 765	107 107	347	342	
6	"	7:45 "	743.6	964 964	407	757 757	107 107	371	350	
7	"	11:30 "	743.4	845 845	531	765 765	122 122	376	357	
8	"	3:30 PM	743.3	833 833	531	763 763	122 122	364	359	
Average				0.08860	0.02502	0.39761	0.51108	0.11362	0.11347	

Set up 10:00 AM, June 4, 1923. Boundaries were put in 4:30 PM, June 4.
The gelatin had less of a tendency to diffuse across the boundaries than in the lower concentrations.





Columns 6, 7, 8 and 9 contain the transference numbers as calculated from the values in Columns 2, 3, 4, and 5 as indicated in the headings. Column 10 contains the sum of the Na and Nc values as given in columns 7 and 9, and should be equal to unity. The accuracy with which the potentials E_H and E_{Cl} can be duplicated in the presence of gelatin is shown by the closeness with which the averages of the tables of the same concentrations agree. The higher concentrations of gelatin show a closer agreement than the lower ones. Table 4 contains a summary of the transference numbers contained in Table 3 together with the boundary potentials in the presence of gelatin.

An inspection of values recorded in Table 4 shows that the values of Na increase with increase in gelatin concentration. The relation between the transference number of the anion and the gelatin concentration is shown in Fig. 2. The transference numbers are plotted as ordinates and the concentrations of gelatin as abscissas. The change in transference number is rapid at low gelatin concentrations. It is gradual between 3 and 5%. Then it slowly rises to a maximum value between 5 and 10%. Above 10% it remains constant. If this represents an actual increase in the migration velocity of the anion, then there must be a corresponding decrease in the boundary potential (E_B). The values given in columns headed Na and E_B indicate such changes. Ferguson (loc. cit) showed in his theoretical development, that the boundary potential opposed the electrode potentials in the hydrogen concentration cell (E_H) and in the chloride concentration cell (E_{Cl}) it is in the same direction as the electrode potentials. If a decrease takes place in E_B there should be an increase in E_H and a corresponding decrease in E_{Cl} . The values in columns E_H and E_{Cl} indicate that such a change takes place.

It has been shown (Equation 6), that the boundary potential depends on the transference numbers of the ions and the ratio of their concentration in the two solutions. Therefore a change in E_B would result from a change in concentration or a change in transference number.

From theoretical considerations the value of E_B would

TABLE III

Summary of Potentials and Transference Numbers with Gelatin.

1	2	3	4	5
Table	E_H	E_{Cl}	$E_H + E_{Cl}$	$E_{0.01}$ $E_{0.1}$
		0.0%		
	0.01947	0.09612	0.11462	0.11463
		0.5%		
1	0.02259	0.09145	0.11403	0.11404
2	<u>0.02258</u>	<u>0.09145</u>	<u>0.11403</u>	<u>0.11405</u>
	0.02259	0.09145	0.11403	0.11405
		0.75%		
1	0.02530	0.08867	0.11397	0.11403
2	<u>0.02566</u>	<u>0.08833</u>	<u>0.11399</u>	<u>0.11400</u>
	0.02548	0.08850	0.11398	0.11402
		1.0%		
1	0.02891	0.08539	0.11430	0.11428
2	0.02731	0.08686	0.11417	0.11397
3.0	0.02757	0.08645	0.11402	0.11402
4	<u>0.02754</u>	<u>0.08655</u>	<u>0.11409</u>	<u>0.11400</u>
	0.02784	0.08631	0.11416	0.11407
		2.0%		
1	0.04476	0.06930	0.11406	0.11408
2	0.04237	0.07167	0.11404	0.11393
3	0.04667	0.06661	0.11329	0.11305
4	<u>0.04646</u>	<u>0.06660</u>	<u>0.11306</u>	<u>0.11305</u>
	0.04507	0.06854	0.11381	0.11370
		2.5%		
1	0.05151	0.06169	0.11321	0.11311
2	<u>0.05153</u>	<u>0.06167</u>	<u>0.11320</u>	<u>0.11317</u>
	0.05152	0.06168	0.11321	0.11314

6	7	8	9	10
$\frac{N_a}{E_H}$	$\frac{N_a}{E_H}$	$\frac{N_c}{E_{Cl}}$	$\frac{N_c}{E_{Cl}}$	$\frac{N_a + N_c}{\text{columns}}$
$E_H + E_{Cl}$	$E_{0.01} - E_{0.1}$	$E_H + E_{Cl}$	$E_{0.01} - E_{0.1}$	7 + 9
		0.0%		
0.16994	0.16991	0.82998	0.82988	0.99979
		0.5%		
0.19811	0.19808	0.80198	0.80190	0.99998
<u>0.19802</u>	<u>0.19798</u>	<u>0.80198</u>	<u>0.80182</u>	<u>0.99980</u>
0.19806	0.19803	0.80198	0.80186	0.99989
		0.75%		
0.22199	0.22187	0.77801	0.77710	0.99947
<u>0.22511</u>	<u>0.22456</u>	<u>0.77488</u>	<u>0.77447</u>	<u>0.99903</u>
0.22355	0.22321	0.77644	0.77604	0.99925
		1.0%		
0.25293	0.25297	0.74706	0.74720	1.00017
0.23920	0.23963	0.76079	0.76214	1.00187
0.24180	0.24180	0.75820	0.75820	1.00000
<u>0.24138</u>	<u>0.24161</u>	<u>0.75861</u>	<u>0.75921</u>	<u>1.00081</u>
0.24388	0.24400	0.75617	0.75669	1.00071
		2.0%		
0.39216	0.39236	0.60757	0.60747	0.99983
0.37153	0.37189	0.62846	0.62907	1.00096
0.41196	0.42827	0.58796	0.58921	1.01748
<u>0.41093</u>	<u>0.41097</u>	<u>0.58907</u>	<u>0.58911</u>	<u>1.00008</u>
0.39664	0.40087	0.60327	0.60371	1.00458
		2.5%		
0.45499	0.45539	0.54492	0.54539	1.00078
<u>0.45521</u>	<u>0.45533</u>	<u>0.54479</u>	<u>0.54493</u>	<u>1.00026</u>
0.45510	0.45536	0.54486	0.54516	1.00052

TABLE III (cont'd)

Summary of Potentials and Transference Numbers with Gelatin

Table	E_H	E_{Cl}	$E_H + E_{Cl}$	$E_{0.01} - E_{0.1}$
		3.0%		
1	0.05635	0.05786	0.11421	0.11416
2	<u>0.05593</u>	<u>0.05793</u>	<u>0.11386</u>	<u>0.11394</u>
	0.05614	0.05790	0.11404	0.11405
		5.0%		
1	0.07437	0.03971	0.11408	0.11426
2	<u>0.07459</u>	<u>0.03973</u>	<u>0.11432</u>	<u>0.11430</u>
	0.07448	0.03972	0.11420	0.11428
		10.0%		
1	0.08150	0.03186	0.11336	0.11344
2	0.08159	0.03206	0.11365	0.11368
3	0.08836	0.02496	0.11332	0.11353
4	0.08817	0.02495	0.11332	0.11320
5	0.09043	0.02313	0.11356	0.11367
6	<u>0.08844</u>	<u>0.02515</u>	<u>0.11360</u>	<u>0.11305</u>
	0.08641	0.02702	0.11347	0.11343
		15.0%		
1	0.08960	0.02412	0.11376	0.11350
2	<u>0.08833</u>	<u>0.02544</u>	<u>0.11377</u>	<u>0.11360</u>
	0.08897	0.02478	0.11377	0.11355
		20.0%		
1	0.08860	0.02502	0.11362	0.11347
2	<u>0.08793</u>	<u>0.02581</u>	<u>0.11374</u>	<u>0.11367</u>
	0.08827	0.02542	0.11368	0.11357

$\frac{N_a}{E_H}$	$\frac{N_a}{E_H}$	$\frac{N_c}{E_{Cl}}$	$\frac{N_c}{E_{Cl}}$	$N_a + N_c$
$E_H + E_{Cl}$	$E_{0.01} E_{0.1}$	$E_H + E_{Cl}$	$E_{0.01} E_{0.1}$	Columns 7 + 9
		3.0%		
0.49339	0.49273	0.50662	0.50683	0.99956
<u>0.49121</u>	<u>0.49087</u>	<u>0.50878</u>	<u>0.50843</u>	<u>0.99929</u>
0.49230	0.49180	0.50770	0.50763	0.99943
		5.0%		
0.65191	0.65088	0.34808	0.34754	0.99842
<u>0.65247</u>	<u>0.65264</u>	<u>0.34753</u>	<u>0.34762</u>	<u>1.00026</u>
0.65219	0.65176	0.34781	0.34758	0.99934
		10.0%		
0.71895	0.71756	0.28105	0.28085	0.99841
0.71789	0.71772	0.28209	0.27207	0.98974
0.77973	0.77823	0.22026	0.21976	0.99804
0.77806	0.77888	0.22008	0.22040	0.99928
0.77631	0.79554	0.20368	0.20348	0.99902
<u>0.77852</u>	<u>0.78231</u>	<u>0.22139</u>	<u>0.22247</u>	<u>1.99821</u>
0.76158	0.76171	0.23926	0.23651	0.99821
		15.0%		
0.78762	0.78942	0.21202	0.21251	1.00193
<u>0.77693</u>	<u>0.77755</u>	<u>0.22361</u>	<u>0.22394</u>	<u>1.00149</u>
0.78228	0.78349	0.21782	0.21823	1.00171
		20.0%		
0.77978	0.78082	0.22021	0.22059	1.00141
<u>0.77309</u>	<u>0.77354</u>	<u>0.22691</u>	<u>0.22707</u>	<u>1.00061</u>
0.77649	0.77718	0.22356	0.22383	1.00101

be reduced by making the concentration of the solutions approach equality. When E_B is equal to zero and when the concentration of the 0.1 M solution became less than the 0.01 M solution, the direction would be reversed.

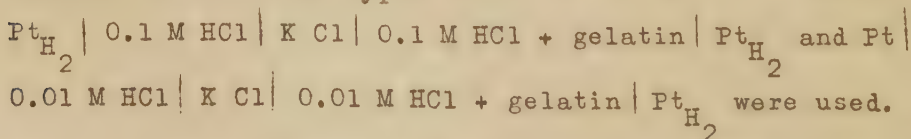
TABLE IV.

Summary of Potentials and Transference Numbers.

% Gel.	E_H	E_{Cl}	N_a	E_B
0.0	0.01947	0.09612	0.16991	0.03783
0.5	0.02259	0.09145	0.19083	0.03560
0.75	0.02548	0.08850	0.22321	0.03187
1.0	0.02784	0.08631	0.24400	0.02948
2.0	0.04507	0.06854	0.40087	0.01290
2.5	0.05152	0.06168	0.45536	0.00514
3.0	0.05614	0.05790	0.49180	0.00094
5.0	0.07448	0.03972	0.65176	-0.01748
10.0	0.08641	0.02702	0.76171	-0.03014
15.0	0.08897	0.02478	0.78349	-0.03264
20.0	0.08827	0.02542	0.77718	-0.03192

I. INFLUENCE OF GELATIN ON THE H^+ ION CONCENTRATION OF HYDROCHLORIC ACID SOLUTIONS.

In order to determine whether or not concentration changes are produced by the addition of gelatin, concentration cells of the type



The data obtained from these measurements are given in Table 5.

TABLE V.

Influence of Gelatin on the H ion Concentration on
 $\frac{M}{10}$ and $\frac{M}{100}$ Hydrochloric Acid Solutions.

% Gel.	0.1 M		0.01 M	
	C_1	E_x	C_2	E_z
0	0.09170		0.00975	
1	0.08791	0.00217	0.00442	0.03946
2	0.08500	0.00391	0.00143	0.09754
3	0.08178	0.00588	0.00095	0.12057
4	0.07864	0.00789	0.00087	0.12421

Due to the foaming of the gelatin solution this value could not be accurately obtained.

The first column contains the percentage of gelatin in the acid in one half the cell. The columns E_x and E_z contain the measured potentials of the cells E_x and E_z when 0.1 M and 0.01 M solutions were used. The hydrogen ion concentrations C_1 and C_2 calculated for the concentrations of gelatin used show that gelatin produces a relatively small decrease of the hydrogen ion concentration in 0.1 M solution and much larger relative decrease in 0.01 M solution. Since the hydrogen ion concentration of the 0.1 M solution is always greater than that of the 0.01 M solution, the reverse of the boundary potential E_B cannot result from concentration changes produced by the gelatin.

Since it has been shown that gelatin produces changes in the hydrogen ion concentration, new potentials are produced at the boundaries between the solutions in the wicks and the gelatin and direction of the boundary

potentials E_B , E_X and E_Z together with E_H and E_{Cl} are shown diagrammatically in Fig. 4.

E_B represents the potential within the siphon, that is, the potential considered thus far, E_X and E_Z represent the potentials at the contact of the solutions in the reservoirs, E_H and E_{Cl} are the measured potentials and are the algebraic sum of the potentials at the electrodes and the boundary potentials E_X , E_B and E_Z .

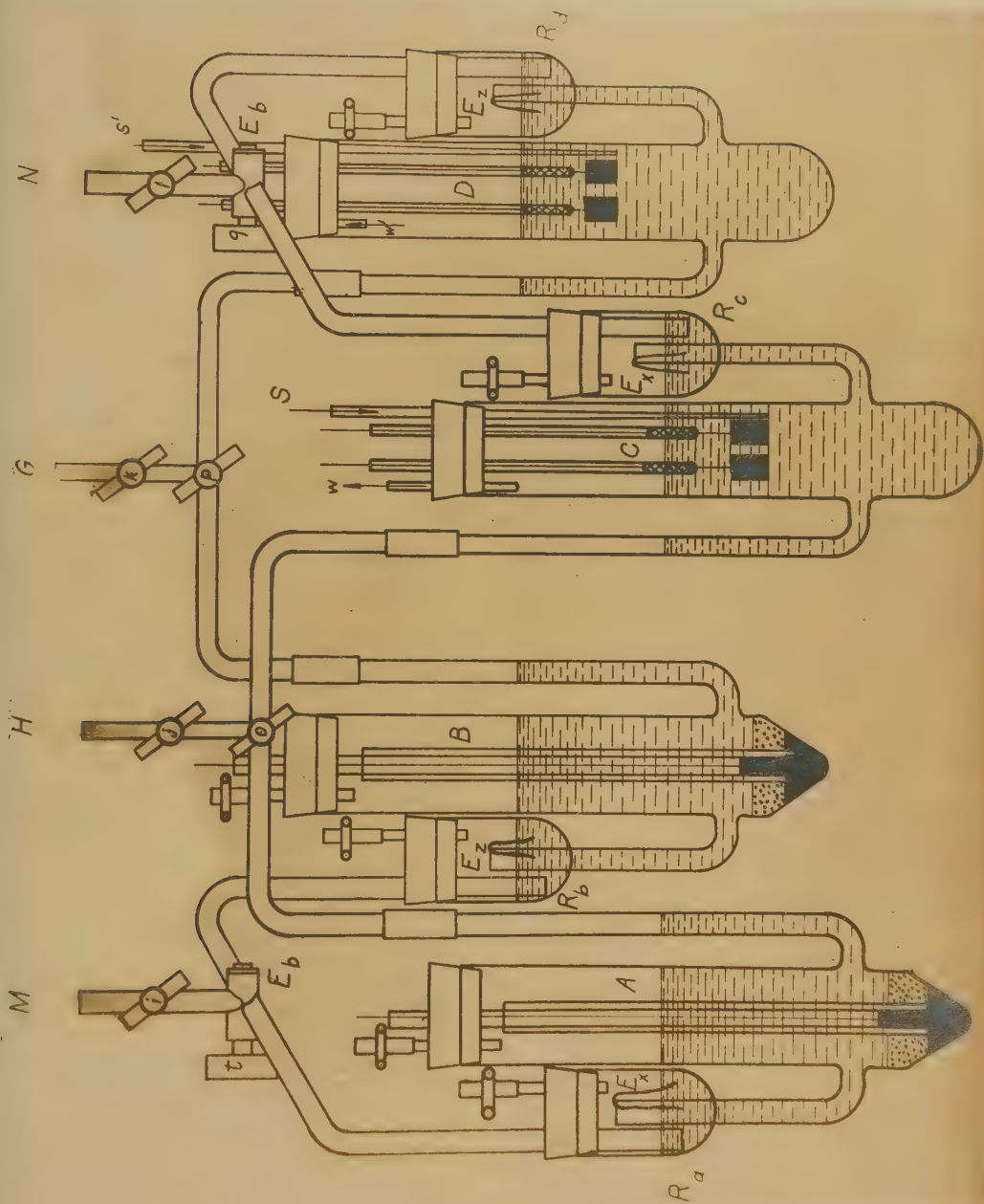
The boundary potentials E'_B , E'_X , and E'_Z were calculated by means of the boundary potential formula

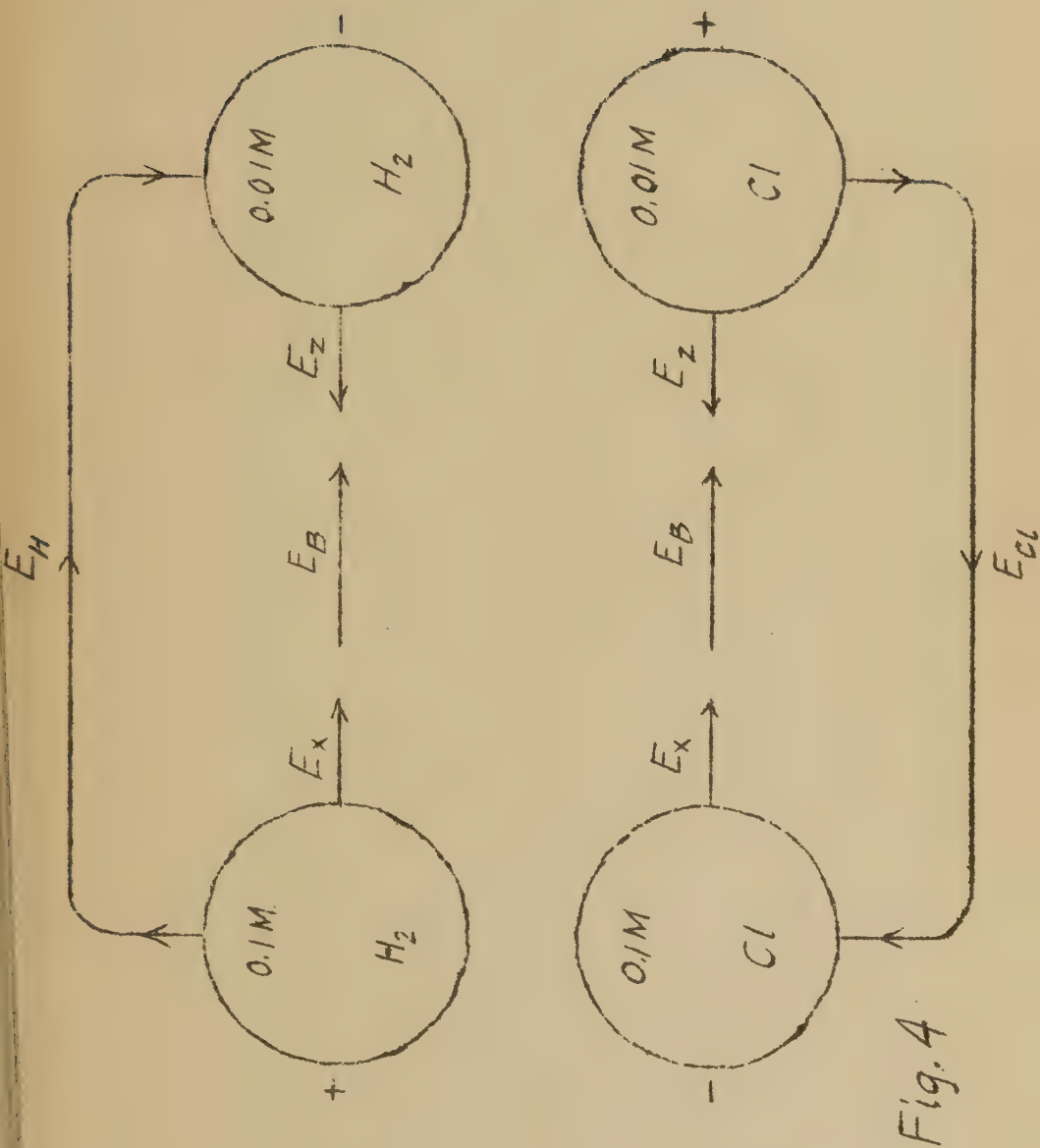
$$E_B = (1 - 2N_a) \frac{RT}{F} \ln \frac{C_1}{C_2}$$

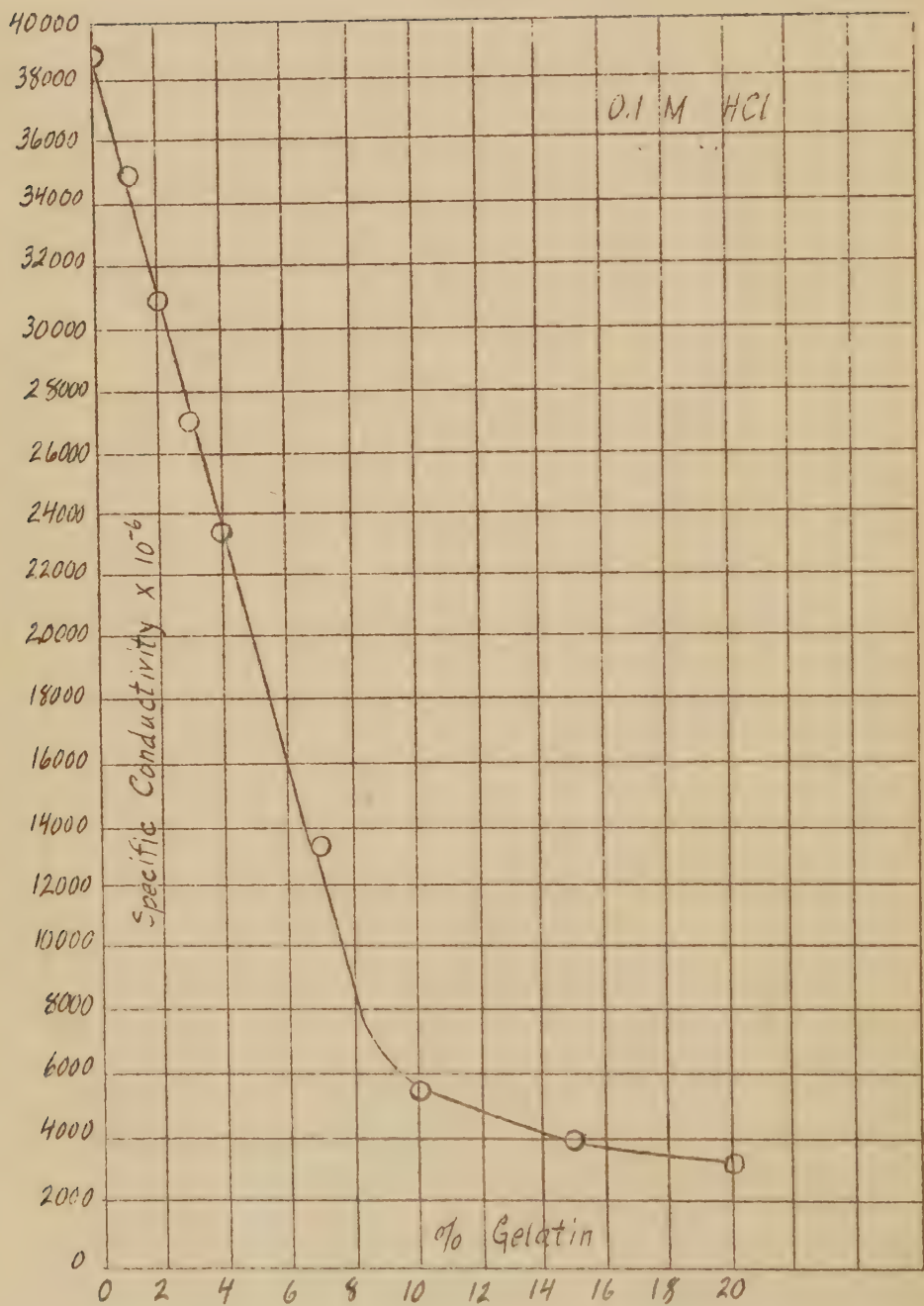
The total potential E'_B should be considered as composed of the original boundary potential plus the potential caused by the alteration of the acid concentration due to the presence of the gelatin. This change in potential should be equal to the total potential E'_B less original boundary potential and is given in column designated $E'_B - 0.03783$. Fig. 4 shows that E_X and E_Z the potentials between the gelatin solutions and the solutions in the wicks are directed in opposition to each other. If the values of E_Z and E_X are due to concentration changes then $E_Z - E_X$ should be equal to $E'_B - 0.03783$. Since they agree satisfactorily this eliminates the possibility that changes observed in the boundary potential are due to concentration changes produced by the addition of gelatin.

2. CONDUCTIVITY OF HYDROCHLORIC ACID SOLUTIONS OF GELATIN.

Any change in the mobility and number of the ions affects the conduction of a solution, therefore, it was thought that conductivity measurements would give some information as to the nature of the changes caused by the addition of gelatin. Measurements were made of the conductivity of 0.1 M and 0.01 M hydrochloric acid solutions,







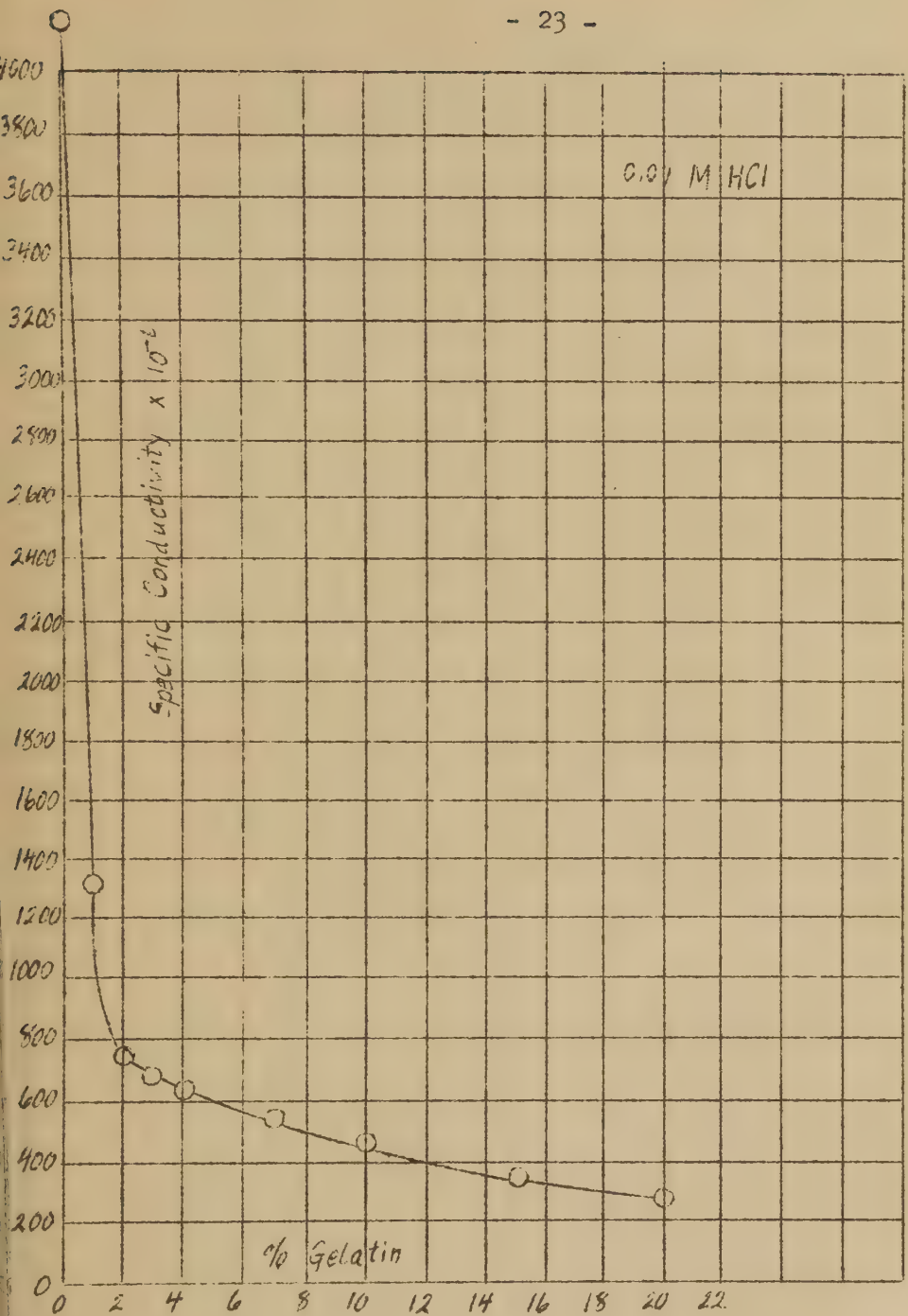


TABLE VI

Boundary Potential Calculations

% Gel.	E_H	E_{Cl}	E_B	E_X	E_Z	$E_Z - E_X$	E'_B	E'_B	0.03783
1	0.02784	0.08631	0.02948	0.00072	0.01342	0.01270	0.05069	0.01286	
2	0.04507	0.06854	0.01090	0.00129	0.03256	0.03127	0.06927	0.03773	
3	0.05614	0.05790	0.00094	0.00194	0.03910	0.03716	0.07556	0.03773	
4.	0.			0.00261	0.04098	0.03837	0.07248	0.03465 [†]	

† The values in line 4 do not check because the 4% gelatin solution foamed so much when hydrogen was bubbled through it that consistent values for the e.m.f. could not be obtained.

in which the concentration of gelatin varied from 0 to 20%. A correction was applied for conductivity of gelatin solutions of water over the same range of concentrations.

Figures 5 and 6 show the effect of gelatin on the conductivity of 0.1 M and 0.01 M solutions of hydrochloric acid. The specific conductivities are plotted as ordinates and the concentrations of gelatin as abscissas. These curves show that the gelatin produces a greater relative change in the specific conductivity of the 0.01 M than in the 0.1 M solutions. This fact is also substantiated by the data in Table 5 which shows that the addition of 3 to 4% of gelatin reduces the hydrogen ion concentration to not far from zero. From Fig. 5, it is seen that 10% gelatin reduces the Conductivity of the 0.1 M solution almost to zero. A similar change occurs in the 0.01 M solution at 2 to 3% concentration of gelatin. This indicates that not only is the hydrogen-ion concentration reduced by the addition of gelatin but also that the acid is removed as a whole.

VI. DISCUSSION OF RESULTS AND CONCLUSIONS.

As has been stated in the introduction, two main theories have been evolved to account for the action of gelatin on electrolytes. The one assumes that a highly dissociable compound is formed either by chemical union or molecular adsorption while the other assumes that the ions of the electrolyte are specifically adsorbed by the gelatin.

This investigation has shown that gelatin exerts a definite influence on the transference number of the anion of hydrochloric acid. A summary of the data obtained is given in Table 4. It shows that the boundary potential has been changed from 0.03783 to -0.03192. Corresponding to this decrease in boundary potential there is an increase in the potential of the hydrogen concentration cell (E_H) from 0.01947 to 0.08827 while there is a decrease in the potential of the chloride concentration cell (E_{Cl}) from 0.09612 to 0.02542. The transference number on the anion has apparently been increased

TABLE VII

Corrected Specific Conductivity of Gelatin and Water.

Gelatin and Water $\times 10^{-6}$	Corrected Value $\frac{M \text{ HCl and Gelatin}}{100}$	Corrected Value $\frac{M \text{ HCl and Gelatin}}{10}$
	$\times 10^{-6}$ 0% Gelatin.	$\times 10^{-6}$
1.00	4093.0 1% Gelatin	38687.3
40.09	1315.41 2% Gelatin	3445.2
67.10	750.3 3% Gelatin	30722.3
90.76	675.44 4% Gelatin	26969.6
114.74	629.16 7% Gelatin	23371.0
171.19	524.5 10% Gelatin	13278.7
206.62	455.28 15% Gelatin	5556.4
246.37	348.43 20% Gelatin	3939.7
260.60	365.60	3092.7

from 0.1699 to 0.7772. This observed effect of a decrease in the boundary potential would be given by any factor which would numerically increase the value E and decrease that of E_{Cl} . This factor would also account for the apparent increase found in the transference number of the anion.

The data given in Table 5 show that this factor cannot be the result of the change in the concentration of the acid solution when the gelatin is added. If this increase was caused by a change of concentration, then the concentration of the hydrogen ions would have to be less in the 0.1 M than in the 0.01 M solutions of gelatin. The recorded data shows this is contrary to the facts. It was also shown that the boundary potentials E'_B -- 0.03783, E_x and E_z which result from concentration changes neutralize each other. Therefore, this effect is not due to concentration changes caused by the addition of the gelatin. This decrease in the boundary potential could be caused by anyone of three factors. A decrease in the concentration of the 0.1 M solution such that it became less than in the 0.01 M solution; a change in the transference number; or a change in the kind of ions present. The data recorded in Table 5 eliminates the first of these factors, because it shows concentration changes are impossible. This shows that the decrease in boundary potential can only be due to the other factors.

The facts are considered from the point of view that a chemical compound which ionizes is formed. If such is the case, there should be a fairly definite relation between the amount of gelatin added and the acid removed. On this basis one would be able to explain the decrease in the hydrogen-ion concentration and in the conductivity which was observed. If such a reaction occurs new compounds are formed and some of the hydrogen ions are replaced by complex gelatin ions which should have a smaller velocity than the hydrogen ions and consequently the transference number of the anion should be increased. This is in agreement with the observed facts. No data from which the exact amount of hydrochloric acid removed by the gelatin could be determined were obtained.

From the curve for the conductivity of 0.1 M hydrochloric acid solution Fig. 5, it appears that the conductivity of the solution is reduced a definite amount for each addition of gelatin. The curve for 0.01 M acid solution Fig. 5 shows similar results. If the compound dissociates, and some evidence has been obtained from

other sources that it does, then the conductivity curves should tend to flatten out at the higher concentrations of gelatin.

This agrees with the observed facts. Moreover, such a compound should possess some conductivity so that for higher concentrations of gelatin the decrease in conductivity would no longer be proportional to the gelatin added. The flattening of the gelatin-hydrochloric acid curve for higher concentrations of gelatin tends to confirm this view. The sharp bend in the conductivity curve for 0.01 M acid solutions Fig. 6 occurs at about the same point as the similar bend in the transference number curve, Fig. 2. In a similar way Table 5 shows that practically all the hydrochloric acid has been removed from the concentration cells for the same concentration of gelatin.

These facts indicate that hydrochloric acid as such is removed by the addition of gelatin to the solution. Therefore, the apparent change in the transference numbers is due not to an actual change in the velocity of the H^+ and Cl^- ions but to the presence of new ions in the solution resulting from the dissociation of the gelatin chloride compound formed.

It has been definitely shown that gelatin causes an increase in the transference number of the anion of hydrochloric acid. Furthermore, it has also been shown that this increase in the transference number of the anion cannot be due to a change in the effective concentration of the acid solutions when the gelatin is added. In view of these facts, the results of this investigation tend to confirm the hypothesis advanced by Ferguson and France that a single dissociable adsorption complex or definite chemical compound is formed by the action of hydrochloric acid and gelatin. In this reaction the H^+ ion of the acid loses its identity. It is also further held that in the presence of a base a similar product would result, in which the OH^- ion of the base would lose its identity. In conformity with this view no similar action should take place between gelatin and a neutral salt.

SUMMARY.

1. A new determination of the transference of the ions of hydrochloric acid has been made.
2. It has been shown that the addition of gelatin reduces the effective H^+ ion concentration of 0.1 M and 0.01 M hydrochloric acid solutions.
3. The transference numbers of 0.1 M and 0.01 M hydrochloric acid have been found to be changed by the presence of gelatin.
4. The presence of gelatin alters the conductivity of 0.1 M and 0.01 M solutions of hydrochloric acid.
5. Some evidence has been found which apparently substantiates the theory that gelatin reacts with acids to form an adsorption complex or additive chemical compound which dissociates.

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AUTOBIOGRAPHY.

I, Walter Harrison Moran, was born at Fair-West Virginia, February 4, 1889. My elementary and secondary education was received in the public schools and the Fairmont State Normal School of that city and my undergraduate college training at the West Virginia University. I received the Bachelor of Arts degree in 1920. From 1913 to 1916 I was in the employ of the Owens West Virginia Battle Machine Company as machine foreman. During the year 1918-1919 I was Du Pont Scholar at the West Virginia University. In 1920-1921 I was a Graduate Assistant in the Department of Chemistry of the Ohio State University, and Assistant in Chemistry, 1921-1923. The requirements for the degree of Doctor of Philosophy were completed at the end of the summer quarter in 1923 and the degree conferred in September 1923.

